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B KEDEM MAY 87 AFOSR-TR-87-1768 AFOSR-82-0187

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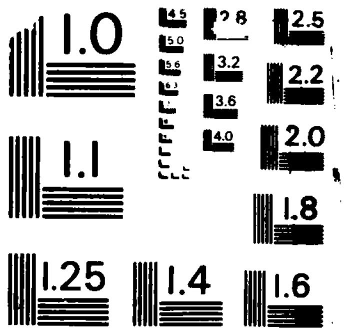

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A graphical device that is useful as a diagnostic tool for higher order crossings was introduced. The graphical tool is also useful as a descriptive similarity measure for time series models. Higher order crossings analysis has been applied to real data, revealing several known periodicities as well as several previously undiscovered periodicit[ies]. The class of strictly oscillatory processes was introduced.

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Final Report on: AFOSR-TR- 87-1768

Higher Order Crossings

Sponsor: AFOSR-82-0187,E

Principal Investigator: B. Kedem, Department of Mathematics, University of Maryland, College Park, MD 20742

Following is the summary of the research activity under the above grant for the academic year 1986/87.

1. HOC Plots

We introduced a graphical device that is useful as a diagnostic tool and also as a descriptive similarity measure for time series models. This graphical tool is in some respects analogous to the usual correlogram [plot of autocorrelation function (ACF)] but portrays information not easily accessible by means of the correlogram. It is based on the actual *oscillation* observed in time series as depicted by axis crossings and higher-order crossings (HOC's). HOC's are axis-crossing counts in differenced time series denoted by $D_{k,N}$ $(k = 1,2,...)$, where k refers to the difference order plus 1 and N to the series length. $D_{1,N}$ denotes the number of axis crossings in the original series (0th difference), $D_{2,N}$ denotes the same number observed in the first difference of the series, $D_{3,N}$ denotes the number of axis crossings in the second difference, and so on. An HOC plot consists simply of the graph of $D_{k,N}$ $(k = 1,2,...)$ for fixed N. This work suggests the use of HOC plots as a practical graphical tool in time series analysis and gives specific examples that support this practice. HOC plots have their own merit, particularly in

discriminating between processes; in addition, they help in the integration of the correlogram itself. Indeed, to a great degree both graphical tools complement one another.

A useful feature of HOC plots is that they provide a way for testing whether the oscillation observed in a given time series matches in some sense the oscillation in a hypothesized process. More precisely, an HOC plot is a graphical means for measuring the difference between observed and expected HOC.

<u>Reference</u>: Higher Order Crossings in Time Series Model Identification. <u>Technometrics</u>, 1987, Vol. 29, 193-204.

2. HOC Analysis of Real Data

Higher order crossings (HOC) analysis was applied to a record consisting of eight years of the Bureau International de l'Heure (BIH) data from 1978 to 1985. The analysis reveals the significance of several periodic components including the Chandler and the annual components. For more conclusive results more data are needed. HOC analysis combines zero crossing counts and linear filtering.

<u>Reference</u>: HOC Analysis of the Earth's Polar Motion from 1978 to 1985, submitted.

3. Strictly Oscillatory Processes

In this work we introduce a class of random processes to which we refer as strictly oscillatory and suggest a method to monitor

the oscillation observed in such processes. When a process is second-order stationary, the oscillation observed in the process is described very effectively by the spectrum. When the process is nonstationary, various attempts have been made to extend the notion of the spectrum to model the time varying spectral content of the process. However, a process need not possess moments at all and still appear to be oscillatory. What is needed then is a way to describe oscillation in random phenomena removed from stationarity assumptions and independent of any moment conditions.

In many respects the simplest way to describe the oscillation observed in a stochastic process, stationary or nonstationary, is through the point processes obtained from higher order crossings. The advantages offered by such zero-crossing counts are as follows:

1. The pattern of oscillation changes can be detected and described directly by zero-crossing counts without recourse to any Fourier analysis. Thus we gain simplicity.
2. The zero-crossing counts observed in finite series in discrete time possess all moments regardless of whether the original process has moments or not. Thus we relax the requirement of finite moments.

Reference: TR87-01, 1987, Department of Math.

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